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Londergan et al.

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(54) **GECKO-LIKE CONTAINER CAPPING SYSTEM AND METHODS**

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USPC 215/43, 316, 232, 319, 320, 321; 220/796, 359.1, 359.2, 287, 805, 285
See application file for complete search history.

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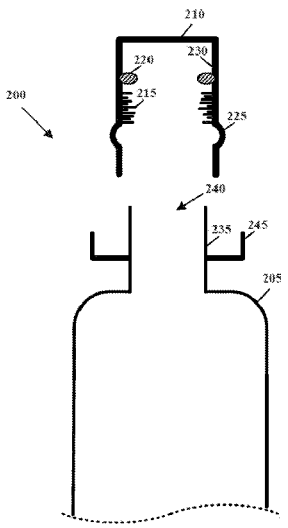
(57) **ABSTRACT**

Methods, systems, caps, containers, and assemblies for a gecko-like container capping system are described. A gecko-like cap configured to cover an opening in a container may include an inner surface configured to mate with an opening surface of a container. Setae may be located on a surface of the cap and/or a surface of the container that are configured to oppose movement of the cap away from the container by creating an adhesion force between the inner surface and the opening surface. The cap may include one or more release mechanisms configured to deflect the inner surface away from the opening surface, thereby reducing the adhesion force such that the cap is removable from the container.

13 Claims, 6 Drawing Sheets



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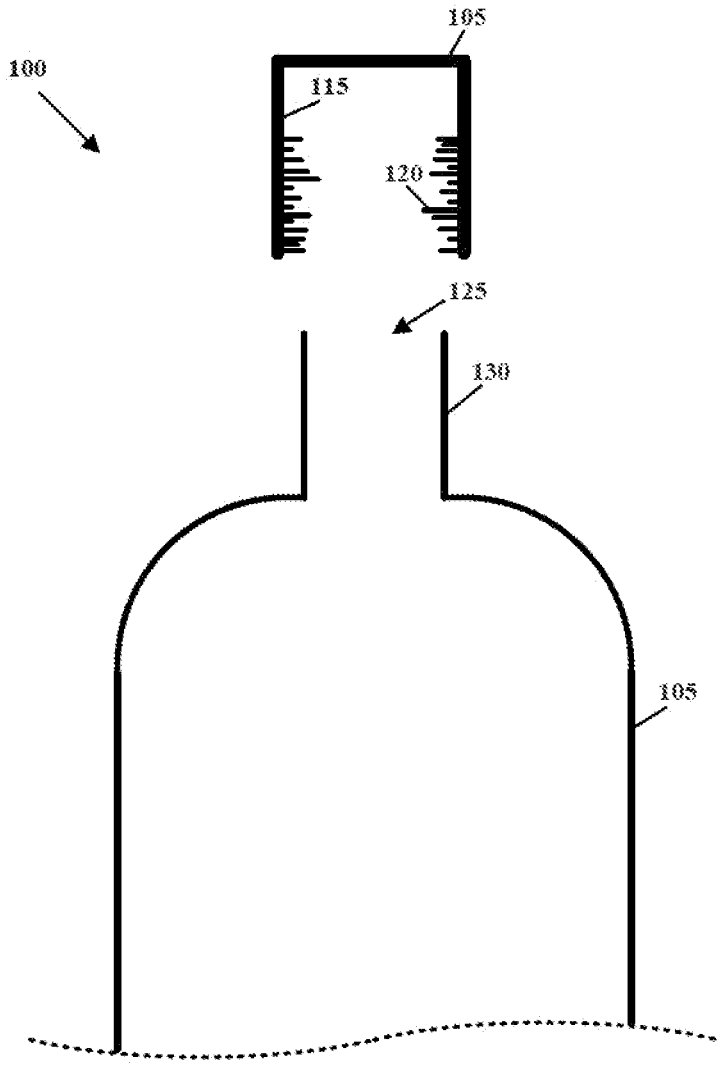

FIG. 1

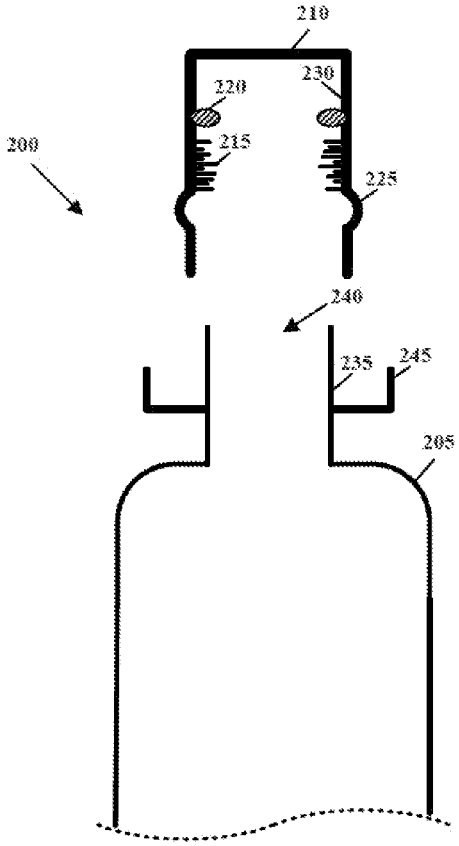
210
220
230
200
215
225
240
235
245
205

FIG. 2A

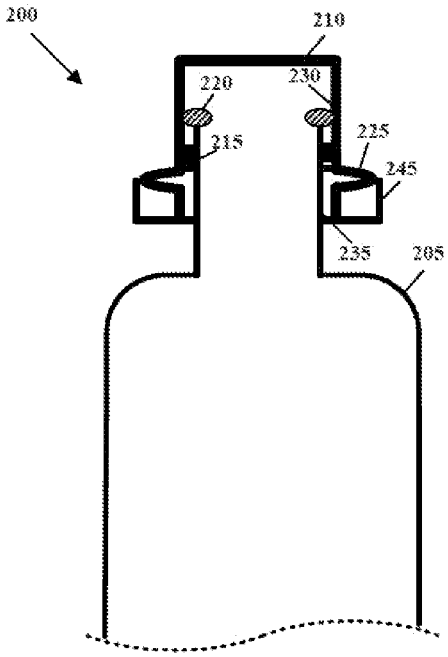
200
210
220
230
215
225
245
235
205

FIG. 2B

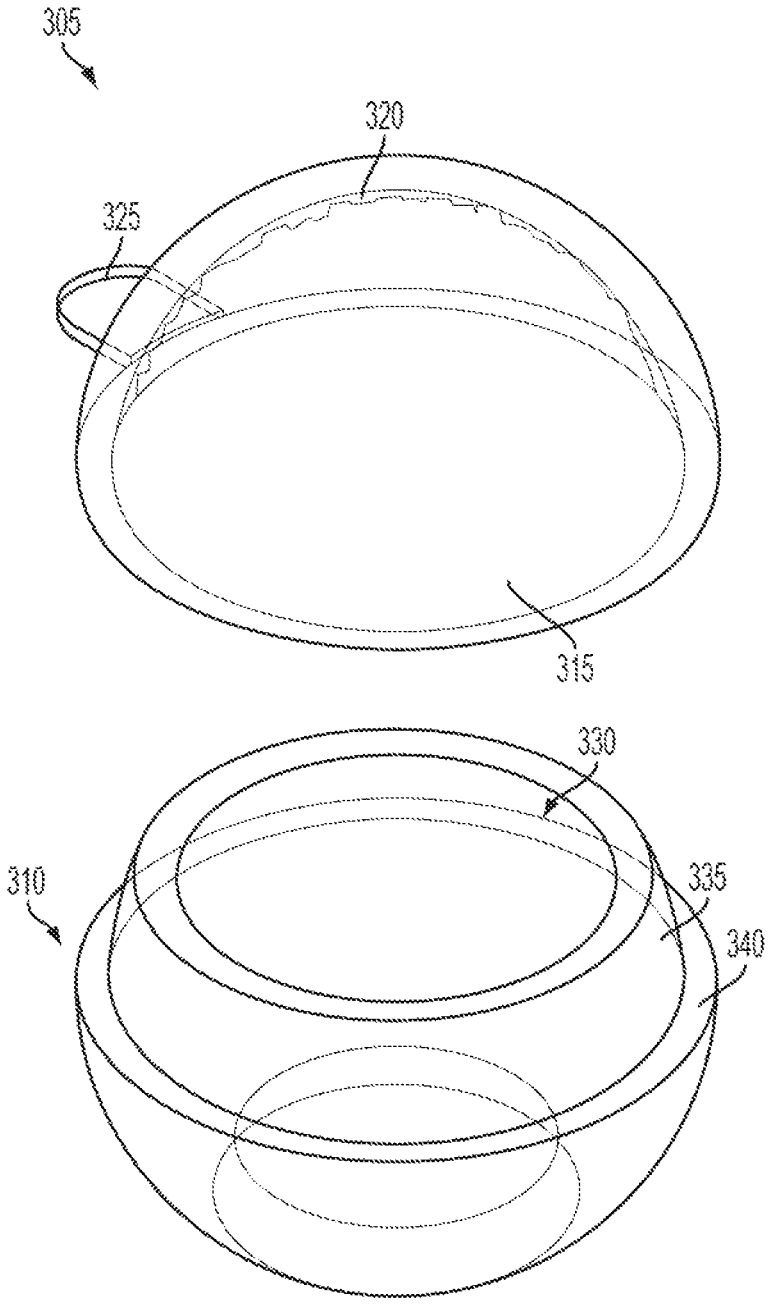

FIG. 3

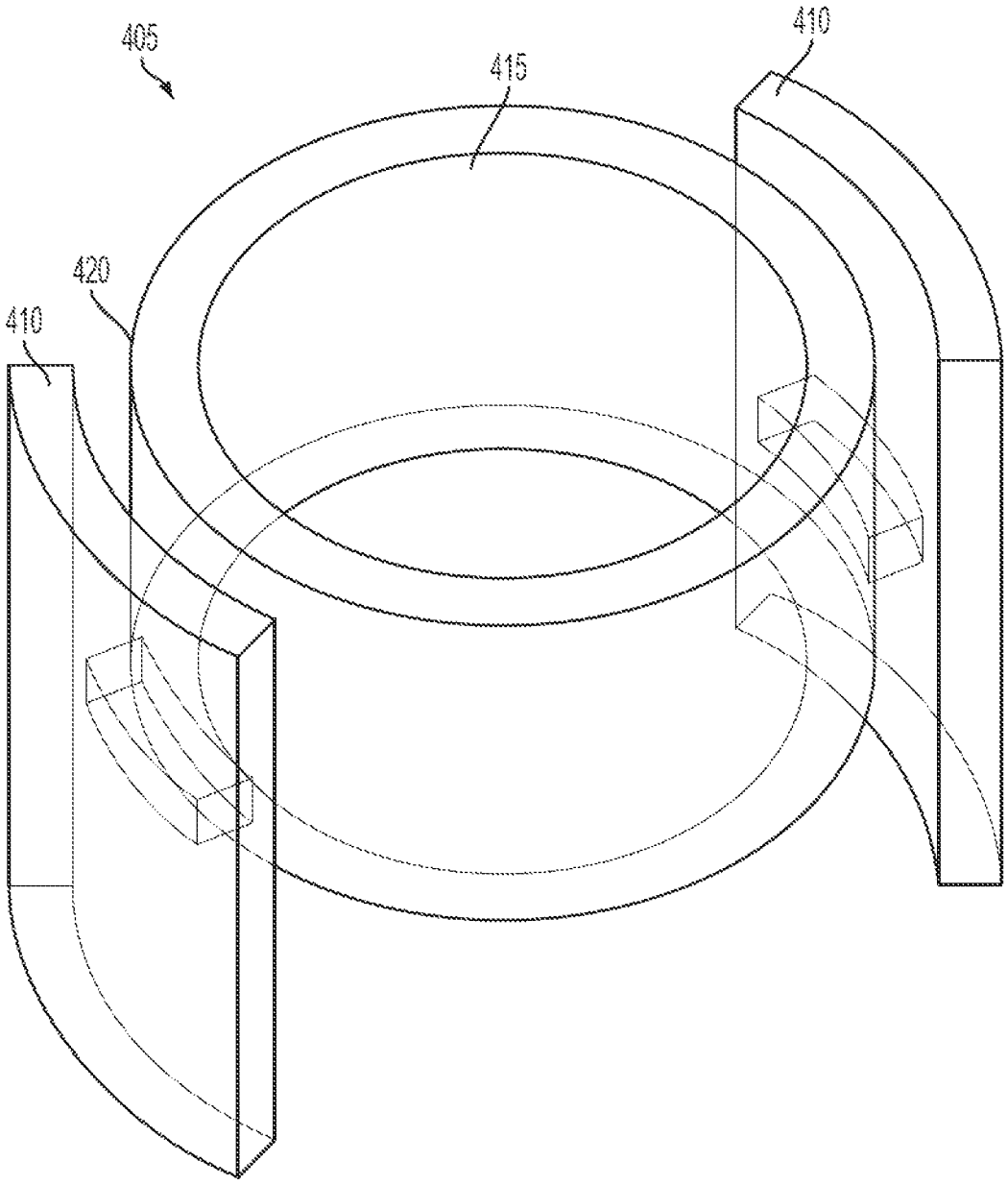

FIG. 4

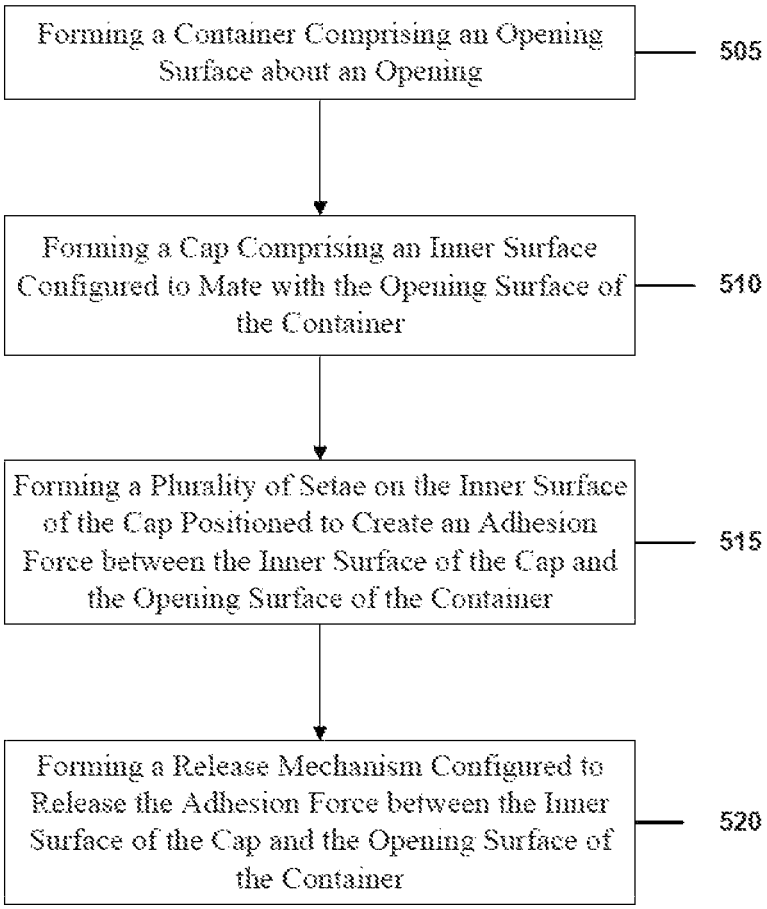
Forming a Container Comprising an Opening Surface about an Opening
505
Forming a Cap Comprising an Inner Surface Configured to Mate with the Opening Surface of the Container
510
Forming a Plurality of Setae on the Inner Surface of the Cap Positioned to Create an Adhesion Force between the Inner Surface of the Cap and the Opening Surface of the Container
515
Forming a Release Mechanism Configured to Release the Adhesion Force between the Inner Surface of the Cap and the Opening Surface of the Container
520

FIG. 5

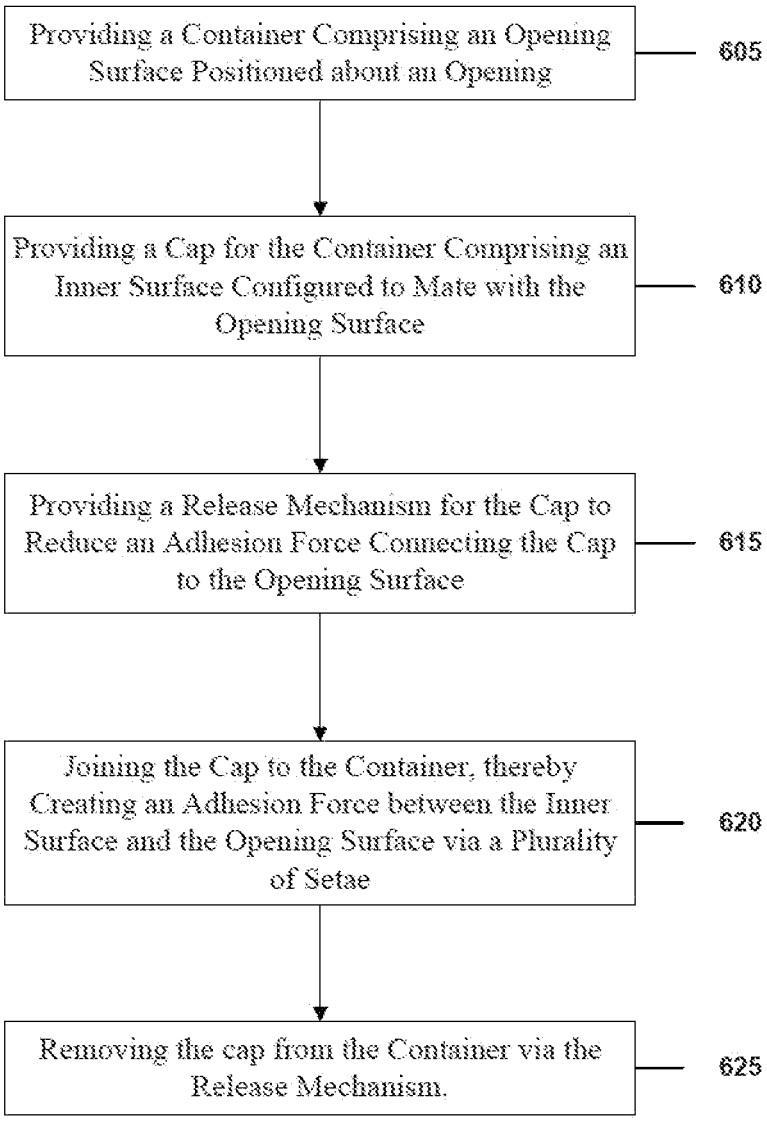
Providing a Container Comprising an Opening Surface Positioned about an Opening
605
Providing a Cap for the Container Comprising an Inner Surface Configured to Mate with the Opening Surface
610
Providing a Release Mechanism for the Cap to Reduce an Adhesion Force Connecting the Cap to the Opening Surface
615
Joining the Cap to the Container, thereby Creating an Adhesion Force between the Inner Surface and the Opening Surface via a Plurality of Setae
620
Removing the cap from the Container via the Release Mechanism.
625

FIG. 6

GECKO-LIKE CONTAINER CAPPING SYSTEM AND METHODS

CLAIM OF PRIORITY

This application is a U.S. national stage filing under 35 U.S.C. §371 of International Application No. PCT/US2012/059002 filed Oct. 5, 2012 entitled "Gecko-Like Container Capping System and Methods," the disclosure of which is incorporated by reference in its entirety.

BACKGROUND

Plastics play a significant role in nearly all aspects of modern life. Consumers repeatedly come into contact with products containing plastic material, ranging from sophisticated medical devices and consumer electronics to more basic products, such as disposable razors. However, plastics also make up a significant percentage of the waste stream generated each year. As a result, much effort has been expended to reclaim and recycle post-consumer plastics, especially food and beverage containers, which represent a large amount of recyclable post-consumer plastic.

In general, food and beverage containers comprise a containing body manufactured from one type of plastic polymer and some form of lid or cap, which is frequently manufactured from a different type of plastic polymer. For example, the ubiquitous water bottle is often made from polyethylene terephthalate (PET) while the bottle caps are often made from polypropylene (PP). When the two materials are mixed together during recycling, one type of material may contaminate the other. This reduces the value of the recycled material and/or requires resources to separate the materials before processing. In many instances, if a plastic container has a cap on it, the entire container is recycled as a unit because consumers are not advised or forget to remove the cap from the container. As such, many plastic-containing products, and food and beverage containers in particular, introduce significant inefficiencies into the post-consumer plastics recycling process.

SUMMARY

This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

In one embodiment, a cap may be configured to cover an opening in a container. The cap may comprise an inner surface configured to mate with an opening surface of a container. The inner surface may comprise a plurality of setae configured to oppose movement of the cap away from the container by creating an adhesion force between the inner surface and the opening surface. The cap may additionally comprise at least one release mechanism configured to reduce the adhesion force such that the cap is removable from the container.

In one embodiment, a method of manufacturing a cap configured to cover an opening in a container may comprise forming an inner surface on the cap configured to mate with an opening surface of a container. A plurality of setae may be formed on the inner surface. The plurality of setae may be positioned to create an adhesion force between the inner surface and the opening surface, thereby opposing movement of the cap away from the container. The method may further comprise forming at least one release mechanism configured to reduce the adhesion force such that the cap is removable from the container.

In one embodiment, a closeable assembly may comprise a container and a cap. The container may comprise an opening surface positioned about an opening. The cap may comprise an inner surface configured to mate with the opening surface of the container. In an embodiment, a plurality of setae may be arranged on the inner surface. In another embodiment, a plurality of setae may be arranged on the opening surface. In a further embodiment, at least a portion of a plurality of setae may be arranged on the inner surface and at least a portion of a plurality of setae may be arranged on the opening surface. The plurality of setae may be configured to oppose movement of the cap away from the container by creating an adhesion force between the inner surface and the opening surface. The closable assembly may further comprise at least one release mechanism configured to reduce the adhesion force such that the cap is removable from the container.

In one embodiment, a method of manufacturing a closeable assembly may comprise forming a container and a cap configured to mate with the container. Forming the container may comprise forming an opening surface about an opening. Forming the cap may comprise forming an inner surface configured to mate with the opening surface of the container. A plurality of setae may be formed that are configured to create an adhesion force between the inner surface and the opening surface, thereby opposing movement of the cap away from the container. In addition, at least one release mechanism may be formed that is configured to reduce the adhesion force such that the cap is removable from the container.

In one embodiment, a method of sealing a container may comprise providing a container and a cap configured to mate with the container. The container may comprise an opening surface positioned about an opening. The cap may comprise an inner surface configured to mate with the opening surface of the container. A plurality of setae may be arranged on the inner surface and/or on the opening surface. The plurality of setae may be configured to oppose movement of the cap away from the container by creating an adhesion force between the inner surface and the opening surface. The method may additionally comprise providing at least one release mechanism configured to reduce the adhesion force such that the cap is removable from the container. The container may be sealed by joining the container and the cap such that the inner surface is positioned adjacent the opening surface, thereby creating an adhesion force between the inner surface and the opening surface via the plurality of setae, the adhesion force opposing movement of the cap away from the container.

In one embodiment, a container configured to receive a cap for closing an opening of the container may comprise an opening surface configured to mate with an inner surface of the cap. The opening surface may comprise a plurality of setae configured to oppose movement of the cap away from the container by creating an adhesion force between the inner surface and the opening surface. The container may further

comprise at least one release mechanism configured to reduce the adhesion force such that the cap is removable from the container.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** depicts an illustrative gecko-like container capping system according to some embodiments.

FIG. **2**A depicts an illustrative gecko-like container capping system in an open position according to some embodiments.

FIG. **2**B depicts an illustrative gecko-like container capping system in a closed position according to some embodiments.

FIG. **3** depicts an illustrative gecko-like container capping system for a bowl-shaped container according to some embodiments.

FIG. **4** depicts an illustrative gecko-like cap according to some embodiments.

FIG. **5** depicts a flow diagram for an illustrative method of manufacturing a cap to cover an opening in a container according to some embodiments.

FIG. **6** depicts a flow diagram for an illustrative method of sealing a container according to some embodiments.

DETAILED DESCRIPTION

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

"Gecko-like" refers to providing adhesive properties by mimicking certain characteristics of the foot of a gecko, such as the Tokay gecko (*Gekko gecko*). In general, a gecko-like structure may comprise a large number of densely packed nano-scale protrusions. Each individual protrusion may only provide a minute amount of adhesiveness; however, collectively, a mass of protrusions may allow for a strong attachment with a contacting surface. In addition, a gecko-like structure may adhere strongly to a surface while providing for relatively easy removal of the gecko-like structure from the surface, especially compared to traditional adhesives of similar strength. Gecko-like structures may be generated from various materials, such as densely packed polymer nanofibers.

A "seta" refers to a nano-scale protrusion formed on a surface of a gecko-like structure. A plurality of setae may collectively provide the adhesive properties of a gecko-like structure. For example, setae may comprise nano-scale fibrils, such as polymer fibrils extruding from an adhesive surface of a gecko-like structure. Each seta may have a certain length and diameter depending on the substrate material and/or desired adhesive properties. For instance, setae may have a diameter of from about 0.1 nm to about 200 μm and a length of from about 0.1 nm to 300 μm.

The present disclosure is directed to gecko-like container capping systems and methods. In an embodiment, the gecko-like container capping system may comprise, consist essentially of, or consist of a container, a cap configured to mate with the container, and gecko-like structures configured to fasten the cap to the container. In some cases, the cap can be tethered to the container, while in other cases they can be untethered. The gecko-like container capping system may be associated with one or more release mechanisms configured to facilitate releasing the cap from the container. The cap and the container may comprise materials, including, without limitation, polyethylene terephthalate (PET), polypropylene (PP), polyethylene, such as high density polyethylene (HDPE), polyimide, or polydimethylsiloxane. In some embodiments, the cap and the container may comprise one or more different materials. In some embodiments, the cap and the container may contain the same or substantially the same material or materials. This may operate, among other things, to greatly increase the efficiency of recycling a container and cap assembly configured according to some embodiments described herein.

FIG. **1** depicts an illustrative gecko-like container capping system according to some embodiments. As depicted in FIG. **1**, the gecko-like container capping system **100** may comprise a container **105** and a corresponding cap **110**. In general, a container **105** may comprise a structure capable of holding a material, such as a bottle or jar, having an opening to receive or release the material. In general, a cap **110** may comprise a structure capable of covering the opening of the container **105**, and is generally shaped to correspond with the shape and size of the opening of the container.

The cap **110** may comprise an inner surface **115** having setae **120** arranged thereon. The cap **110** may be configured to receive the opening surface **130** of an opening **125** of the container **105**. The inner surface **115** of the cap **110** may mate with the opening surface **130** of the container **105** such that the setae **120** contact the opening surface and oppose movement of the cap away from the container, for example, by creating an adhesion force between the inner surface and the opening surface. In an embodiment, the opening surface **130** may be smooth or may comprise one or more patterns, protrusions, and/or setae configured to facilitate adhesion with the setae **120** arranged on the cap **110**.

The container **105** may be closed by placing the cap **110** on and around the opening **125** and pressing down on the cap such that the cap covers the opening and the setae **120** make effective contact with the opening surface **130**. In an embodiment, effective contact of the setae **120** with the opening surface **130** comprises contact sufficient for the setae to adhere to the opening surface and oppose or prevent movement of the cap **110** away from the container **105**. For example, effective contact may result in adhesion between the container **105** and the cap **110** such that human intervention (e.g., pulling the cap away from the container) is required to remove the cap from the container. In another example, effective contact may operate to fasten the cap **110** to the container **105** such that the container is sealed by the cap, including providing a water tight and/or air tight seal.

The container **105** and the cap **110** may comprise various materials. The materials may be petroleum based, polysaccharide-based, protein-based, or a combination thereof. The materials may be biodegradable. Illustrative materials include high density polyethylene (HDPE), low density polyethylene (LDPE), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS), polyimide, polydimethylsiloxane, poly(lactic acid) (PLA), chitosan, gelatin, epoxy resin, post-consumer resin (PCR), K-resin, and combinations thereof. In an embodiment, the container **105** and the cap **110** comprise the same or substantially the same material or materials. In addition, all or part of the container **105** and/or the cap **110** may be made by conventional injection molding processes.

Although the setae **120** in FIG. **1** are depicted as being formed on the cap **110**, and the inner surface **115** in particular, embodiments are not so limited. According to some embodiments, the setae **120** may be formed on the container **105** and/or the cap **110** in various locations. A non-limiting example provides that the setae **120** may be formed on the container, such as on and around the opening surface **130**. In another non-limiting example, the setae **120** may be formed on both the container **105** and the cap **110** in either substan-

tially equal or disparate portions. In this example, at least a portion of the setae **120** may be formed on the container **105** and at least a portion of the setae may be formed on the cap **110**.

The setae **120** may be formed, for example, from the inner surface **115** of the cap **110** and/or the opening surface **130** of the container **105**, through various setae formation processes. Selecting a setae formation process may depend on several factors, including, without limitation, the cap and/or container material(s), preferred adhesiveness properties, cost, manufacturing processes, and combinations thereof. Illustrative and non-restrictive examples of setae formation processes include electrospinning, photo- or electron-beam lithography, nanoimprinting, roll-to-roll printing, nanolithography, nanomachining, ion etching, molecular self-assembly, ultrasonic vibration assisted hot embossing or nanoimprinting, and combinations thereof.

In an embodiment, the container **105** may comprise a polymer (e.g., PET) and the setae **120** may be stamped onto an outer surface of the container, such as the opening surface **130**. For example, the setae **120** may be formed using a silicone mold in combination with ultrasonic vibration-assisted nanoimprinting. In this embodiment, the mold may be pressed against the opening surface **130** and subjected to ultrasonic vibrations that generate heat sufficient to cause the mold to press the setae **120** into the compositional material of the opening surface **130**. In another embodiment, the setae **120** may be formed by a nanoimprinting process using a stamping mold from inside of the cap **110**. For example, a shaped nanoimprinting mold with a smaller diameter than the inner diameter of the cap **110** may be heated above the melting point or deformation temperature of the material or materials used to make the cap. The heated mold may be quickly rolled along the inner wall of the cap **110** with sufficient pressure to generate the setae **120**. A further embodiment provides that the setae **120** may be generated on the inner surface **115** of the cap **110** by an in-mold lamination method. In this method, a nano-fiber pattern may be formed on the inner surface **115** by printing on a polymer film, such as a PET film, using electrospinning techniques. The resulting film may be cut into appropriately sized pieces and set on an inner mold of an injection molding system configured to generate the cap **110**. When the cap **110** is generated through the injection molding process, the setae **120** may be formed on the inner surface **115**.

In an embodiment, the setae **120** may be continuous with the surface from which they are formed. For example, the setae **120** may be continuous with the inner surface **115** in that the setae may comprise a region of the inner surface molded to form protrusions that make up the setae. In another embodiment, the setae **120** may be formed on a separate piece of material and combined with the container **105** and/or the cap **110**. For instance, the setae **120** may be formed from a separate piece of material (which may or may not be the same material that makes up the container **105** and/or the cap **110**) and may be combined with the container and/or cap when forming the gecko-like container capping system **100**. For example, the setae **120** may be molded onto a separate substrate and combined with the container **105** and/or the cap **110** through a molding or adhesive process. In another example, the setae **120** may be formed or roll-to-roll printed on a gecko-like adhesive tape, gel, or other structure that may be combined with the container **105** and/or the cap **110** as part of the gecko-like container capping system **100**.

The setae **120** may comprise setae characteristics, including, without limitation, materials, chemical compositions, potential container contents and/or uses, adhesive strength, container and/or cap configurations, release properties, and combinations thereof. For example, the setae **120** characteristics may include, without limitation, length, diameter, density, material, location, and surface area **115**. The setae characteristics may be configured to achieve certain effects, such as cap placement, adhesiveness, ease/difficulty of release, container performance characteristics (e.g., exposure to certain temperatures), and combinations thereof.

According to some embodiments, one or more of the setae **120** characteristics may be determined based on a length and/or diameter of the setae. In some embodiments, the setae **120** may have a diameter from about 0.2 μm to about 0.5 μm, from about 0.1 nm to about 10 μm, from about 1 nm to about 1 μm, from about 1 μm to about 1 μm, from about 10 nm to about 20 nm, from about 100 nm to about 500 nm, from about 200 nm to about 1 μm, and from about 50 μm to about 150 μm. Specific illustrative diameters include about 0.1 nm, about 1 nm, about 10 nm, about 100 nm, about 1,000 nm, about 2,000 nm, about 3,000 nm, about 4,000 nm, about 5,000 nm, and ranges between any two of these values. In some embodiments, the setae **120** may have a length from about 0.1 μm to about 500 μm, from about 10 μm to about 250 μm, from about 50 μm to about 150 μm, from about 10 nm to about 50 nm, from about 50 nm to about 100 nm, from 1 μm about 100 μm, from about 5 μm to about 150 μm, from about 30 μm to about 130 μm, from about 50 μm to about 150 μm, and from about 100 μm from about 250 μm. Specific illustrative lengths include about 0.1 μm, about 10 μm, about 50 μm, about 100 μm, about 200 μm, about 300 μm, about 400 μm, about 500 μm, and ranges between any two of these values. In an embodiment, the setae **120** may have a diameter of about 100 nm and a length of about 200 μm.

According to some embodiments, the setae may be hierarchical or single strained, angled or not angled, straight or curly, branched or unbranched, or some combination thereof. In an embodiment, a seta may be a single pillar. In some embodiments, a seta may be further branched out into hundreds of spatula, with length and diameter dimensions of from about 2 μm to about 5 μm long and from about 100 nm to about 200 nm in diameter.

In some embodiments, the setae may have an aspect ratio of from about 1 to about 7, from about 4 to about 10, from about 10 to about 15, from about 15 to about 20. According to some embodiments, the setae may have an aspect ratio of about 6, about 10, about 12, about 13, about 14, about 16, or about 18.

According to some embodiments, the setae may have a density of from about 10,000 per mm^2 to about 2 million per mm^2. In some embodiments, the setae may have a density of about 50,000 per mm^2, about 100,000 per mm^2, about 200,000 per mm^2, about 400,000 per mm^2, about 500,000 per mm^2, about 600,000 per mm^2, or about 1 million per mm^2.

FIG. **2**A depicts an illustrative gecko-like container capping system in an open position according to some embodiments, while FIG. **2**B depicts an illustrative gecko-like container capping system in a closed position according to some embodiments. In some cases, as depicted in FIG. **2**A, the gecko-like container capping system **200** may comprise, consist essentially of, or consist of a container **205** and a cap **210**. In some cases, the cap **210** can be tethered to the container **205**, while in other cases they can be untethered. Setae **215** may be formed on an inner surface **230** of the cap **210**.

The cap **210** may comprise a spring mechanism **225** configured, for instance, as a spring-like structure at the lower end of the cap. In an embodiment, the spring mechanism **225** may comprise a monocock structure. The spring mechanism **225** may be engaged when the gecko-like container capping system **200** is in the closed state, as depicted in FIG. **2**B and

described in more detail below. According to some embodiments, the spring mechanism **225** may be located at an upper end of the cap **210**, for example, above the setae **215** and/or the one or more dimple structures **220**, or in the middle of the cap. As such, the location of the spring mechanism **225** is not limited, as the spring structure may be located in a suitable location where it may operate according to embodiments described herein.

The container **205** may comprise an opening **240** having an opening surface **235**. A stopper mechanism **245** configured to interface with a lower portion of the cap **210** may be located on the opening surface **235**.

Referring to FIG. **2**B, when the cap **210** is pushed downward, sliding along the opening surface **235** of the container **205**, the lower portion of the cap may abut the stopper mechanism **245**. In an embodiment, the stopper mechanism **245** and/or the cap **210** may be configured such that the lower portion of the cap fits securely into the stopper mechanism. The stopper mechanism **245** may additionally operate to prohibit the cap **210** from expanding, for example, and releasing pressure or becoming detached from the container **205**.

As depicted in FIG. **2**B, the cap **210** may be pushed onto the container **205** causing the setae **215** to contact the opening surface **235** of the container. The setae may be compressed against the opening surface **235**, fastening the cap **210** to the container **205**. As the cap **210** is pushed onto the container **205**, the cap and/or the spring mechanism **225** may be pressed against the stopper mechanism **245**. For example, the spring mechanism **225** may abut the stopper mechanism **245** when the cap **210** is pressed onto the container **205**, contracting the spring mechanism, thereby generating a force that engages the spring mechanism. The engaged spring mechanism **225** may exert a force that presses the inner surface **230** and, therefore, the setae **215** against the opening surface **235**, promoting adhesion of the setae to the opening surface. In an embodiment, the engaged spring mechanism **225** may be configured to provide a resistive force on the cap **210**. The resistive force may be parallel to the direction of the adhesion force provided by the setae **215**, which is parallel to the inner surface **230**. The engaged spring mechanism **225** may operate to push the cap **210** in the opening direction along the opening surface **235**, reinforcing the adhesion force at the location where the setae **215** contact the opening surface.

The gecko-like container capping system **200** may comprise one or more release mechanisms to aid in removal of the cap **210** from the container **205**. In an embodiment, a release mechanism may comprise one or more dimple structures **220** arranged, for example, at the upper end of the inner surface **230**. In an embodiment, the closed container **205** may be opened by pushing the cap **210** further down in a closing direction (e.g., further down from the closed position) to further compress the spring structure **225** and cause the dimple structures **220** to reduce the adhesion force between the inner surface **230** and the opening surface **235**. For example, when the cap **210** is pushed further down from the closed position, the dimple structures **220** may slide down against the setae **215**, peeling the setae from the opening surface **235**, thereby breaking the adhesion force between the cap and the container **205**. In another example, when the cap **210** is pushed further down from the closed position, the dimple structures **220** may deflect the opening surface **235** away from the inner surface **230** such that the setae **215** no longer contact the opening surface or do not have sufficient contact as to generate the adhesion force necessary to prevent removal or relatively easy removal of the cap.

In an embodiment, when the cap **210** is pushed further down from the closed position and adhesion between the cap and the container **205** has been sufficiently reduced, the spring mechanism **225** may expand and operate to push the cap upward to promote removal of the cap from the container (as opposed to the inward force generated when the container and cap are in the closed position).

The setae **215** may differentially adhere to a surface based on the direction that the setae are being pressed against or removed from the surface. For example, the setae **215** may adhere to the container **205** when being pressed against the opening surface **235** in a direction parallel to the surface containing the setae (e.g., the inner surface **230**), such as when the cap **210** is being placed on the container. The adhesion force of the setae **215** may be reduced or substantially non-existent when the setae contact or move about the opening surface **235** in a direction other than being pressed against the opening surface in a direction parallel to the surface containing the setae. For example, twisting the cap **210** about the opening **240** may reduce or eliminate the adhesion force generated by the setae **215** and facilitate removal of the cap from the container **205**.

FIG. **3** depicts an illustrative gecko-like container capping system for a bowl-shaped container according to some embodiments. As depicted in FIG. **3**, the bowl-shaped container **305** may comprise an opening **330** formed by an opening surface **335** and a stopper mechanism **340** configured to receive a lower portion of the cap **310**. The cap **310** may comprise an inner surface **315** having setae **320** arranged thereon and a release mechanism **325** configured to facilitate the release of the cap **310** from the bowl-shaped container **305**.

The cap **310** may be pushed onto the container **305** such that the inner surface **315** of the cap **310** comes into contact with the opening surface **335** of the container **305** and the lower portion of the cap **310** comes into contact with the stopper mechanism **340**. In this position, the setae **320** may be pressed against the opening surface **335**, generating an adhesion force that fastens the cap **310** to the container **305**.

As depicted in FIG. **3**, the release mechanism **325** may generally involve a tab-like structure protruding from the lower portion of the cap **310**. Pulling on the release mechanism **325** may, for example, deform the cap **310** and/or pull the cap away from the container **305**, releasing the setae **320** from the opening surface **335**. In this manner, the cap **310** may be efficiently removed from the container **305** notwithstanding the strong adhesive properties provided by the setae **320**.

FIG. **4** depicts an illustrative gecko-like cap according to some embodiments. The cap **405** may comprise an inner surface **415** having setae (not shown) arranged thereon. One or more spring mechanisms **410** may be associated with the cap **405**. In an embodiment, the spring mechanisms **410** may be compressed and engaged when the cap **405** is positioned on a container (not shown), providing a force that presses against the cap body **420**. The force against the cap body **420** may be transferred to the inner surface **415** of the cap **405**, thereby adding to one or more existing forces or introducing one or more forces that press the setae against the container. In another embodiment, the spring mechanisms **410** may de-compress when the cap **405** is removed from the container, providing a force in a direction away from the container that facilitates removal of the cap **405** from the container.

FIG. **5** depicts a flow diagram for an illustrative method of manufacturing a cap to cover an opening of a container according to some embodiments. A container may be formed **505** comprising an opening surface about an opening. In an embodiment, the opening surface may form a neck of the container, such as the neck of a conventional beverage container. The container may be formed **505** of various suitable

materials, including, without limitation, high density polyethylene (HDPE), low density polyethylene (LDPE), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS), post-consumer resin (PRC), K-resin, and combinations thereof. In an embodiment, the container may be formed **505** using an injection molding process.

A cap may be formed **510** comprising an inner surface configured to mate with the opening surface of the container. The cap may be formed **510** to correspond with the opening of the container, for example, to conform to the size and shape of the opening and/or the opening surface. In an embodiment, the cap may be formed **510** such that the inner surface contacts the opening surface of the container. Processes similar to those used to form **505** the container, such as injection molding processes, may be used to form the cap. The cap may comprise suitable materials according to some embodiments described herein, including materials used to form **505** the container as described herein. In an embodiment, the container and the cap may be formed **505**, **510** of the same or substantially the same material or materials.

A plurality of setae may be formed **515** on the inner surface of the cap, positioned to create an adhesion force between the inner surface of the cap and the opening surface of the container when the cap is positioned on the container. The setae may be formed **515** according to various suitable processes, including processes presently known or developed in the future, capable of generating setae configured to perform according to some embodiments described herein. Non-limiting examples of processes for forming **515** the setae include plastic electrospinning, nanoimprinting, and lithography. The setae **515** may be formed on the inner surface of the cap and may provide an adhesion force between the inner surface of the cap and the opening surface of the container when the inner surface of the cap is pressed against the opening surface of the container.

A release mechanism may be formed **520** that is configured to release the adhesion force generated by the setae between the inner surface of the cap and the opening surface of the container. In an embodiment, the release mechanism may comprise one or more dimple structures, for example, located at a top position inside the cap. The release mechanism may be formed **520** to operate according to various methods. For example, by forcing a structure between the setae and the container to peel the setae away from the container, by deflecting an opening surface of the container away from the cap, and combinations thereof, effectively reducing or releasing the adhesion force between the setae and the opening surface of the container. The release of the adhesion force allows for the cap to be removed or more easily removed from the container.

FIG. **6** depicts a flow diagram for an illustrative method of sealing a container according to some embodiments. A container may be provided **605** comprising an opening surface positioned about the opening. For example, a food container may be provided **605** comprising an opening for receiving food formed by an opening surface arranged about the opening. A cap for the container may be provided **610** comprising an inner surface configured to mate with the opening surface. In an embodiment, the inner surface of the cap and the opening surface of the container may be formed of a complementary or substantially complementary shape and size, such that the inner surface may come in contact or close contact with the opening surface when the cap is placed on the container opening. A plurality of setae may be arranged on the inner surface of the cap. The plurality of setae may be configured to adhere to the opening surface of the container, for example, when pressed against the opening surface of the container.

A release mechanism may be provided **615** for the cap to reduce and/or release an adhesion force connecting the cap to the container. In an embodiment, the release mechanism may be configured to deflect the inner surface away from the opening surface, thereby reducing the adhesion forces holding the cap to the container.

The cap may be joined **620** to the container such that the inner surface of the cap is positioned adjacent to the opening surface of the container, thereby creating an adhesion force between the inner surface and the opening surface via the plurality of setae. In an embodiment, joining the cap to the container may cause the setae to press against the opening surface of the container. Pressing the setae against the container may result in an adhesion force capable of fastening the cap to the opening surface of the container.

The cap may be removed **625** from the container using one or more release mechanisms. The release mechanisms may be configured to facilitate the removal or reduction of the adhesion force generated by the setae. In an embodiment, a release mechanism may comprise one or more dimple structures arranged within the cap. The dimple structures may be configured to reduce the adhesion forces responsive to the cap being pushed down further from a closed position. For example, pushing the cap down further may cause the dimple structures to deflect the opening surface of the container away from the setae, peeling the setae away from the opening surface, sufficiently reducing the adhesion force such that the cap may be removed from the container.

EXAMPLES

Example 1

Gecko-Like Water Bottle Container System

A container will be manufactured from HDPE by an injection molding process in the form of a conventional water bottle. The water bottle will have an opening formed by an opening surface in the shape of a bottle neck. A stopper configured to receive the lower portion of a cap will be formed on the neck. The cap will be manufactured from HDPE by an injection molding process. Setae will be formed on an inner surface of the cap following completion of the injection molding process using a nanoimprinting process. During the nanoimprinting process, a stamping mold configured to imprint setae in an HDPE substrate will be heated above the deformation temperature of HDPE and rolled against the inner surface of the cap, forming a collection of setae within the cap. The cap will have a release mechanism in the form of two dimple structures located above the setae on opposite sides of the inner surface of the cap. A spring mechanism will be located below the setae at a lower portion of the cap.

Pushing the cap down onto the neck of the water bottle will cause the setae to contact the neck and the lower portion of the cap to contact the stopper. When the lower portion of the cap contacts the stopper, the force of pushing the cap down will be directed toward contracting the spring mechanism. When the spring mechanism is contracted such that it is engaged, it will impart a force on the body of the cap generating pressure forcing the setae against the neck of the water bottle. The setae will generate an adhesion force fastening the cap to the water bottle and the water bottle and cap will be in a closed position.

When the cap is in the closed position, pushing the cap further down will engage the release mechanism. The dimple

structures of the release mechanism will press against an outer surface of the neck of the water bottle and deflect the neck away from the setae. The setae will peel away from the neck and the adhesion force between the setae and the neck will be reduced and the cap will be removed from the water bottle. When the cap is being pulled upward, away from the container, the spring mechanism will expand and impart a force in an opening direction, away from the container, that further facilitates the removal of the cap from the water bottle.

Example 2

Gecko-Like Food Container System

When manufactured, a food container will have a substantially square shape and will be formed from PP. The food container will include an opening and an opening surface about the opening. A stopper in the form of a ridge will be located at the bottom of the opening surface. A gecko-like cover for the container will be formed out of PET and will generally conform to the size and shape of the container opening surface, being slightly larger such that it will fit around the opening surface. Setae will be formed on and around an inner surface of the gecko-like cover and will be configured to contact the opening surface. The setae will be formed as nano-fiber mats created through an electrospinning process. The gecko-like cover will include a release mechanism in the form of an elongated tab protruding out from one corner of the gecko-like cover.

Pressing the gecko-like cover down against the opening surface of the container until it comes into contact with the stopper will cause the setae to contact the opening surface and generate an adhesion force sufficient to form a substantially water tight seal. Pulling out and up on the release mechanism will deform the gecko-like cover and reduce the adhesion force such that the gecko-like cover will be removed from the container.

Example 3

Container Cap Having a Gecko-Like Inner Surface

An approximately 5 μm-thick polyimide film will be baked at about 250° C. on top of a silicon wafer. An array of submicrometer aluminum disks will be prepared using electron-beam lithography, thermal evaporation of an aluminum film and lift-off. The resulting aluminum pattern will be transferred to the polyimide film by dry etching in oxygen. The oxygen plasma etching will provide a large difference between etching rates of aluminium oxide and polyimide, such that several micrometers of polyimide will be removed before the aluminium disk disappears.

A negative direct current (DC) bias will be applied to the substrate to achieve large aspect ratios, making the pillars sufficiently tall. The polyimide will be peeled from the silicon wafer and transferred onto the inner surface of a container cap by using an adhesive to provide a container cap having a Gecko-like inner surface.

Example 4

Bottle Cap for Sealing Various Materials in a Container

A container will be manufactured from PET by an injection molding process in the form of a water bottle. The water bottle will have an opening formed by an opening surface in the shape of a bottle spout. A corresponding bottle cap for the water bottle will be manufactured from PP by an injection molding process.

A smooth inner surface of the bottle cap will be fitted with suction cup tape that includes an acrylic foam sheet with microscopic suction cups formed on both sides. The suction cup tape will be or will be similar to Regabond-S suction cup tape made commercially available by the Exel Trading Co., Ltd of Tokyo, Japan.

The bottle cap will be fastened to the bottle spout such that the suction cup tape will contact an outer surface of the bottle spout. The bottle cap and bottle spout will become affixed and form a leak-proof seal such that the bottle will contain liquid and solid substances without unwanted releases of the substances.

The bottle cap will be removed responsive to manual squeezing of the bottle cap combined with pulling upward (e.g., away from the bottle) on the bottle cap. Manual squeezing of the bottle will deflect the bottle cap away from the bottle such that contact between the suction cup tape on the inner surface of the bottle cap and the outer surface of the bottle spout will be disrupted, allowing the bottle cap to be released and easily removed.

In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds, compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.).

While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

What is claimed is:

1. A cap configured to cover an opening in a container, the cap comprising:

an inner surface configured to mate with an opening surface of a container, the inner surface comprising a plurality of setae configured to oppose movement of the cap away from the container by creating an adhesion force between the inner surface and the opening surface; and

at least one release mechanism configured to reduce the adhesion force such that the cap is removable from the container through at least one of contacting at least a portion of the plurality of setae to peel the portion of the plurality of setae away from the opening surface and contacting the opening surface to deflect the opening surface away from the inner surface.

2. The cap of claim **1**, further comprising at least one spring mechanism configured to provide a resistive force between the inner surface and the opening surface in a direction that is parallel to a direction of the adhesion force.

3. The cap of claim **1**, wherein each of the plurality of setae has a diameter of about 10 nm to about 100 μm.

4. The cap of claim **1**, wherein each of the plurality of setae has a length of about 10 μm to about 500 μm.

5. The cap of claim **1**, wherein the cap comprises a same material as the container.

6. The cap of claim **1**, wherein the cap comprises at least one of high density polyethylene, low density polyethylene, polyethylene terephthalate, polyvinyl chloride, polypropylene, polystyrene, post-consumer resin, K-resin, acrylonitrile butadiene styrene, polylactic acid, acryl resin, and combinations thereof.

7. The cap of claim **1**, further comprising at least one tab release mechanism configured to reduce the adhesion force via deflecting the inner surface away from the opening surface.

8. The cap of claim **1**, wherein the at least one release mechanism is configured to reduce the adhesion force such that the cap is removable from the container through contacting at least a portion of the plurality of setae to peel the portion of the plurality of setae away from the inner surface.

9. The cap of claim **1**, wherein the at least one release mechanism is configured to reduce the adhesion force such that the cap is removable from the container through contacting the opening surface to deflect the opening surface away from the inner surface.

10. A container configured to receive a cap for closing an opening of the container, the container comprising:

an opening surface configured to mate with an inner surface of the cap, the opening surface comprising a plurality of setae configured to oppose movement of the cap away from the container by creating an adhesion force between the inner surface and the opening surface;

at least one release mechanism configured to reduce the adhesion force such that the cap is removable from the container; and

a stopper mechanism configured to receive a spring mechanism of the cap, the spring mechanism being configured to provide a resistive force between the inner surface and the opening surface in a direction that is parallel to a direction of the adhesion force.

11. The container of claim **10**, wherein the container comprises a same material as the cap.

12. The container of claim **10**, wherein the container comprises high density polyethylene, low density polyethylene, polyethylene terephthalate, polyvinyl chloride, polypropylene, polystyrene, post-consumer resin, K-resin, acrylonitrile butadiene styrene, polylactic acid, acryl resin, and combinations thereof.

13. The container of claim **10**, wherein the inner surface comprises at least a portion of the plurality of setae.

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